RESEARCH ON THE QUALITY OF THE EGG SHELL
(A NEW METHOD OF DETERMINATION)

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In connection with the continually increasing demand for a product of good quality, research on the quality of the egg shell has become of more and more importance during the last few years, as the quality of the shell contributes considerably to the preservation of the quality of the egg contents.

Research into the quality of the egg shell is mainly concerned with research on the shell strength, as it is of the utmost importance for the preservation of the quality of the egg contents that the shell does not crack during the different stages through which the egg passes from producer to consumer. A complete crack of the shell, as well as the appearance of hair cracks, degrades the egg to a second class product. Both types of cracks strongly depend upon the quality of the shell which, in its turn, is mainly determined by the strength and thickness of the shell.

The measurement of shell strength can, among other things, be estimated by measuring shell thickness. Apart from this way of measuring shell strength, there are other indirect methods to get an idea of the shell strength, and these are, among other things, the determination of the percentage shell and the specific gravity of the egg.

A full review article about measuring shell strength appeared recently by Tyler (1961). Tyler discusses here the different methods, used by several research workers, for measuring the shell strength by a direct method. All these methods come down to determining in some way the energy of a ball needed to crack the shell, when the ball is dropped on the egg. The disadvantage of these methods is that such determinations are not reproducible and that by this treatment the egg loses its value as a consumption egg. The measurement of shell strength with the aid of an apparatus which cracks the shell has also the disadvantage that this way of measuring definitely does not equal the cracking caused by transport. In measuring the shell thickness and in determining the percentage shell, the egg has also lost its value as a consumption egg. Up till now, the only method of obtaining some knowledge of the shell strength, without affecting the value of the egg as consumption egg, is the indirect method of measuring the specific gravity of the whole egg. This measurement of specific gravity is really an indirect method of measuring the percentage shell. The disadvantage of the specific gravity as measure for the shell strength is that it is only of value when all the eggs, which are judged and compared with each other, have been kept after laying for the same amount of time and under the same conditions of temperature and relative humidity of the air, before the measurement takes place. A study of the relation between specific gravity and the percentage shell has been published by Olson (1934).

In 1959, in collaboration with the Institute T.N.O. for: Mechanical Constructions in Delft, an apparatus was designed for measuring the changes in shape of an egg shell which occur from a certain load. The new apparatus (Fig. 1) has been named deformation apparatus.

The apparatus consists of a stand (1) with platform (2; 3) on which the egg can be placed. At the top of the stand is a horizontal bar (11), which can be moved up and down the stand by means of a slide (8). Attached to this horizontal bar is a measuring clock (5) and the pin (12), which presses through the measuring clock on the egg shell. The measuring clock can register changes in shape with an accuracy of 1 μ, whereas 0.5 μ can be estimated. On top of the horizontal bar projects the pin, which can be placed on the egg shell. On this no selected load can be put. In measuring the deformation of an egg shell, the egg is put on the platform (3), where it is supported by three metal plates which make an angle of 45° with the horizontal. The egg can therefore be put in any position—i.e. on its small end, on its large end, or on its equator. Care must be taken that the egg is placed in such a way that the pin, which has next to be placed on the egg, presses perpendicularly on the surface of the shell. This can be regulated by moving the platform backward and forward (4). The horizontal bar (with pin, clock and load) is now screwed down by aid of the right knob (6) on the upper part of the stand until the pin nearly touches the surface of the egg. With the precision screw (10) under the load, the pin is now placed on to the shell surface, whereby the needle of the measuring clock comes within the graduation. With the lever (9) the load is just lifted and with the precision screw the needle is adjusted to the O-point of the scale of the clock. With aid of the load (7) the required pressure can be put on the shell by carefully releasing the lever (9). For our comparative investigation the same weight is always used, viz. 500 g., a load every egg can bear in shape.

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When we follow under influence of a linear relationship degree of change in which also shows deformation can a cracking than a shell Figure 2 also show curve in deformation the differences in a deformation lines the egg shell fall degree of change in (11b-17μ). This fi
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The shell strength of eggs, which are kept, have been kept at a certain temperature under the relative humidity of 1934.

In order to ascertain whether it makes any difference to the reliability of the measurement where, on the surface of the egg shell, the deformation is determined, the deformation and thickness of the shell were determined in 100 eggs, on the large end, as well as on the small end, and at three points on the equator.

Normally we take for the shell thickness the average of measurements on the large end, the small end, and at three points on the equator. So we have first determined the deformation on the same points. After these various measurements, the correlation is calculated between the average shell thickness (of large end, small end, and equator) and respectively the deformation of the large end, the deformation of the small end and the deformation of the equator. This is the average of the three measurements on a distance of 120° along the equator each time. The results obtained are represented in Table 1.

Table 1 Correlation coefficients between deformation and shell thickness, measured at different points on the egg shell.

<table>
<thead>
<tr>
<th>Correlation Coefficient</th>
<th>Large End</th>
<th>Small End</th>
<th>Equator</th>
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<tbody>
<tr>
<td>r</td>
<td>-0.16</td>
<td>P&lt;0.01</td>
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<tr>
<td>r</td>
<td>-0.17</td>
<td>P&lt;0.01</td>
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<tr>
<td>r</td>
<td>-0.45</td>
<td>P&lt;0.01</td>
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<tr>
<td>r</td>
<td>-0.71</td>
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These correlation coefficients indicate, in the first place, that there is a close relation between deformation and shell thickness. Further, the correlation coefficients are highest for the measurements on the equator. This is explained by the fact that the shell thickness on the equator shows less variation than on the large end or the small end, where irregularities are often found. The deformation at three different points on the equator shows, therefore, less variability and will thus give a higher correlation coefficient with the shell thickness than when the measurements are taken on other points.

For the best results, it is therefore recommended to measure the deformation on the equator and not on the large end or the small end.

Before the deformation apparatus was used for routine work, a number of testing measurements were made, of which some will be mentioned here. To get an idea of the differences in absolute value of the deforma-
The following figures are given of the deformation found on the eggs of some types of birds. For the eggs of guinea-fowls the deformation was 10.1μ; for Barnevelders 19.9μ; for Sussex × R.I.R. 21.5μ; for W.L. × R.I.R. 27.7μ; for Khaki Campbell ducks 30.0μ; and for Peking ducks 17.3μ.

The above-mentioned mean deformation figures, which are not specific for species or breed, were related to the figures for breaking strength, percentage shell, and shell thickness, found on the same eggs. From some 100 eggs of these three types of birds the correlation coefficients were calculated, whereby the following figures were found:

- Deformation/Percentage shell = -0.768
- Deformation/Shell thickness = -0.743
- Deformation/Breaking strength = -0.591

After the above results had been obtained, the new apparatus was used in an experiment, in which the first 10-30 eggs of 60 experimental laying hens were gathered under the same circumstances. The breaking strength, shell thickness, deformation, and percentage shell were evaluated. The correlation between the various shell characteristics was established from the figures thus obtained, making use of the hen averages of the 60 hens for each characteristic (see Table 2).

These correlations can be called high for a biological product such as eggs. The correlation coefficients between the deformation and the breaking strength, and the deformation and the percentage shell can be called high in this case. From the course of the deformation under increasing weight (see Figure 2) it follows that the breaking strength and deformation are more or less a similar function of the shell. This is also the case with shell thickness and percentage shell, because the percentage shell increases when the shell becomes thicker.

From this it follows that the relationship between deformation and breaking strength will be extra high (−0.82), just as the relationship between shell thickness and percentage shell (−0.84). We also see that the correlation between the deformation and shell thickness or percentage shell (respectively −0.758 and −0.803) is higher than between breaking strength and shell thickness or percentage shell (respectively +0.652 and +0.625). Thus a preliminary conclusion can be drawn that the deformation is perhaps a better measure for the shell strength (respectively quality) than the breaking strength.

To obtain more certainty about the suitability of the deformation as a measure for the shell strength, an experiment following these calculations of correlation has been carried out, which investigated the relationship between the previously evaluated deformation and the breaking which normally packed.

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breaking which occurs during transport in eggs normally packed.

This experiment was carried out with 360 eggs with a weight of not less than 50 g. and not more than 70 g. each. The eggs were packed on ordinary egg trays in a wooden 30-dozen egg case. Due to the transport, 50 eggs were broken. The percentage of eggs with dented shells was 11.7 and the percentage of eggs with hair-cracked shells was 2.5.

The results of this transport experiment are represented in Figure 3, where the deformation of the eggs is represented on the horizontal axis and the percentage of broken eggs from a certain deformation class on the vertical axis. We see that, when the deformation increases, the percentage of eggs broken due to transport increases as well.

The eggs with a very small deformation remain practically all intact; from the eggs with the most common deformation (16-24%) the percentage which breaks is considerably higher, whereas many of the eggs with an abnormally high deformation broke during transport.

References
Olson, N. (1934).—"Studies on specific gravity of hens' eggs. A new method for determining the percentage of shell in hens' eggs." (O. Harrassowitz: Leipzig.)